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TRACY W. DRUCE, ESQ. 1496 EVANS FARM DR MCLEAN, VA 22101				LOUIS JACQUES, JACQUES H
ART UNIT		PAPER NUMBER		
		3661		

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Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	10/708,213	LINGMAN ET AL.	
	Examiner	Art Unit	
	Jacques H Louis-Jacques	3661	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) Responsive to communication(s) filed on 17 February 2004.
2a) This action is **FINAL**. 2b) This action is non-final.
3) Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4) Claim(s) 1-23 is/are pending in the application.
4a) Of the above claim(s) _____ is/are withdrawn from consideration.
5) Claim(s) _____ is/are allowed.
6) Claim(s) _____ is/are rejected.
7) Claim(s) 6 and 17 is/are objected to.
8) Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9) The specification is objected to by the Examiner.

10) The drawing(s) filed on _____ is/are: a) accepted or b) objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11) The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12) Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) All b) Some * c) None of:
1. Certified copies of the priority documents have been received.
2. Certified copies of the priority documents have been received in Application No. _____.
3. Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) Notice of References Cited (PTO-892)
2) Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08)
Paper No(s)/Mail Date 21704.

4) Interview Summary (PTO-413)
Paper No(s)/Mail Date. ____ .
5) Notice of Informal Patent Application (PTO-152)
6) Other: ____ .

DETAILED ACTION

Drawings

1. The drawings are objected to because (1) the different boxes need to be properly labeled, e.g., box 34 should be labeled "calculation device" (see figures 1-2, 4); (2) the drawing figures are too big, they extend out on the page margins (see figures 1-4); (3) in figure 2, there are seven (7) inputs into box 40; however, eight (8) input data are listed. Furthermore, in figure 2, each input data should be labeled by a reference number and enclosed with a "box" for better understanding. Figure 3 represents different graphs. Each graph should be labeled separately (e.g., Fig. 3A, 3B, etc.). Corrected drawing sheets are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. The figure or figure number of an amended drawing should not be labeled as "amended." If a drawing figure is to be canceled, the appropriate figure must be removed from the replacement sheet, and where necessary, the remaining figures must be renumbered and appropriate changes made to the brief description of the several views of the drawings for consistency. Additional replacement sheets may be necessary to show the renumbering of the remaining figures. The replacement sheet(s) should be labeled "Replacement Sheet" in the page header (as per 37 CFR 1.84(c)) so as not to obstruct any portion of the drawing figures. If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

Specification

2. The disclosure is objected to because of the following informalities: reference to the claims (number and preamble) is inappropriate since the numbering and language of the claims may change during prosecution. See paragraphs [0002], [0009], [0010].

In paragraph [0056}, the sentence “The vehicle's mass can therefore be estimated simultaneously by utilizing the control force $f(t)$ according to the above, by the relationship $a(t) =$ This means that when the input signal from an accelerometer is used, ...” is incomplete. It is not clear which relationship is being referred to.

Appropriate correction is required.

Claim Rejections - 35 USC § 101

3. 35 U.S.C. 101 reads as follows:

Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

Claims 1-23 are rejected under 35 U.S.C. 101 because the claimed invention is directed to non-statutory subject matter. The claim are directed to neither a “process” nor a “machine,” but rather embrace or overlap two different statutory classes of invention set forth in 35 U.S.C. 101 which is drafted so as to set forth the statutory classes of invention in the alternative only. In *Ex parte Lyell*, 17 USPQ2d 1551 (Bd. Pat. App. & Inter. 1990). See MPEP 2173.05.

Claim Rejections - 35 USC § 112

4. The following is a quotation of the second paragraph of 35 U.S.C. 112:

Art Unit: 3661

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

5. Claims 1-23 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

6. Claim 1 recites the limitation "a calculation device" in line 8. There is insufficient antecedent basis for this limitation in the claim. It is not clear whether the "calculation device" recited in line 5 is the same as the one recited in line 8.

In line 1, claim 1 refers to "the mass of a vehicle", whereas in line 11, "the weight of the vehicle" is recited.

Claim 7 recites "said parameter", whereas claim 1 refers to "a variable".

Applicant is suggested to stay consistent with the terminology used through the claims.

Claim 1 recites "a statistical representation of a road with varying gradient", whereas claim 5 recites, "said statistical representation of the gradient of the road", which is different from the recitation in claim 1.

While a few examples have been given above, Applicant is suggested to review all the claims and provide appropriate correction.

7. Claims 1-23 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for reciting (i.e., claiming) both an apparatus and a method. In *Ex parte Lyell*, 17 USPQ2d 1548 (Bd. Pat. App. & Inter. 1990). See MPEP 2173.05.

8. The following rejections are based on the Examiner's best interpretation of the claims in light of the deficiencies as noted above.

Claim Rejections - 35 USC § 103

9. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

10. Claims 1-5, 8-16, and 18-23 are rejected under 35 U.S.C. 103(a) as being unpatentable over Bellinger et al [6,567,734] in view of WO 02/39073 to Puputti et al.

Bellinger et al discloses a system and method for estimating vehicle mass. According to Bellinger et al, a vehicle acceleration and a vehicle drive force are determined and used in determining or estimating the vehicle mass. According also to Bellinger a vehicle speed (36) (columns 2 and 6) is determined (106), which is then used along with the drive force (124) in the estimation of the vehicle mass (126). See column 9. Vehicle acceleration computed from vehicle speed data. However, when vehicle acceleration is used to determine the vehicle mass, a noise problem is encountered. Therefore, using vehicle speed in the estimation of the vehicle mass provides reliable, accurate estimates of vehicle mass. As described in columns 20-22, Bellinger et al uses a recursive process for determining the vehicle mass, wherein the recursive process generates simultaneous estimates of the mass of the vehicle and the gradient of the road on which the vehicle is being driven. See also column 19. According further to Bellinger et al, the longitudinal force component is calculated from an estimate of torque delivered from an engine (14) in said vehicle (figure 1). The engine, according to Bellinger et al, consists of an internal combustion engine (14) (column 2), wherein the delivered torque is estimated on the

basis of information concerning the amount of fuel supplied to the combustion chamber of the internal combustion engine and the operating speed (column 2) of the internal combustion engine (figures 1 and 2A). See column 11. As explained in columns 11 and 12, the delivered torque is estimated from a torque sensor placed in association with the vehicle's transmission line. The force, according to Bellinger et al, is calculated from the delivered torque and information concerning the current gearing between the drive shaft from the internal combustion engine and the vehicle's current driving wheels (columns 11 and 12). According still to Bellinger et al as set forth in columns 20-22, in particular, information regarding the mass of the vehicle is used for the apportionment of braking force between brakes in the vehicle's tractor unit and trailer. Bellinger et al does not particular that the filter is a Kalman filter or alternatively an extended Kalman filter. Puputti et al, on the other hand, discloses a method and arrangement for determining weight of load of a vehicle, wherein the weight (mass) of the vehicle is determined using a non-linear Kalman filter. Thus, it would have been obvious to one skilled in the art at the time of the invention to be motivated to modify the r a system and method for estimating vehicle mass of Bellinger et al by incorporating the non-linear Kalman filter from the method and arrangement of Puputti et al because such modification would provide a more accurate and sufficient weigh/mass estimation.

11. Claims 1-5, 8-16, and 18-23 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zhu et al [6,167,357] in view of WO 02/39073 to Puputti et al.

Zhu et al discloses a recursive vehicle mass estimation. According to Zhu et al both the vehicle and road gradient (coefficient) are determined. In estimating the vehicle mass and the road gradient, a vehicle speed and push force are measured (determined) and subsequently used in the estimation. See abstract, figure 2 and column 2. According to Zhu et al, the force is calculated from an estimate of torque delivered from an engine in the vehicle, wherein the engine consists of an internal combustion engine and the delivered torque is estimated on the basis of information concerning the amount of fuel supplied to the combustion chamber of the internal combustion engine and the operating speed of the internal combustion engine (column 2). Furthermore, the delivered torque is estimated from a torque sensor placed in association with the vehicle's transmission line and the force is calculated from the delivered torque and information concerning the current gearing between the drive shaft from the internal combustion engine and the vehicle's current driving wheels (column 2). As described in columns 9 and 10, in particular, Zhu et al discloses that the vehicle speed, the force and the gradient are filtered. However, Zhu et al does not particular that the filter is a Kalman filter or alternatively an extended Kalman filter. Puputti et al, on the other hand, discloses a method and arrangement for determining weight of load of a vehicle, wherein the weight (mass) of the vehicle is determined using a non-linear Kalman filter. Thus, it would have been obvious to one skilled in the art at the time of the invention to be motivated to modify the recursive vehicle mass estimation of Zhu et al by incorporating the non-linear Kalman filter from the method and arrangement of Puputti et al because such modification would provide a more accurate and sufficient weigh/mass estimation.

Allowable Subject Matter

12. Claims 6 and 17 would be allowable if rewritten to overcome the rejection(s) under 35 U.S.C. 112, second paragraph, set forth in this Office action and to include all of the limitations of the base claim and any intervening claims.

The applied prior art references do not particular the statistical representation of the gradient of the road consists of a first order process with an intensity d and a switching frequency, wherein the size of said intensity d and the switching frequency are updated on the basis of information concerning the gradient of the road generated from said recursive process.

Conclusion

13. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

5,610,372	Phillips et al	Mar. 1997
6,249,735	Yamada et al	Jun. 2001
6,339,749	Rieker et al	Jan. 2002
6,347,269	Hayakawa et al	Feb. 2002
6,625,535	Han et al	Sep. 2003

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jacques H Louis-Jacques whose telephone number is 703-305-9757. The examiner can normally be reached on M-Th 6:30 AM to 5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black can be reached on 703-305-8233. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jacques H Louis-Jacques
Primary Examiner
Art Unit 3661

/jlj

Jacques H. Louis-Jacques
JACQUES H. LOUIS-JACQUES
PRIMARY EXAMINER

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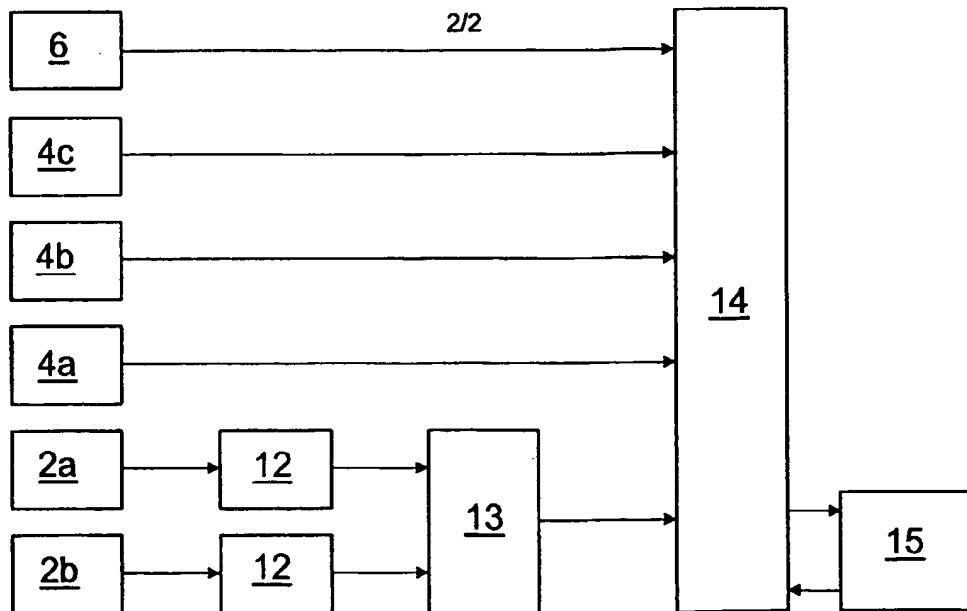
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(72) Inventors; and

(75) Inventors/Applicants (for US only): PUPUTTI, Jarmo
[FI/FI]; Kraatarinkatu 1 A 1, FIN-33270 Tampere (FI).
SAVIA, Mariaana [FI/FI]; Opiskelijankatu 4 B 114,

[Continued on next page]

(54) Title: METHOD AND ARRANGEMENT FOR DETERMINING WEIGHT OF LOAD IN MINING VEHICLE



WO 02/39073 A1

(57) Abstract: A method and an arrangement for determining the weight of a load in a mining vehicle, in which method and arrangement a non-linear Kalman filter is used to determine the weight (m) of the load.



CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ,*
- *SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*
- *of inventorship (Rule 4.17(iv)) for US only*

Published:

- *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND ARRANGEMENT FOR DETERMINING WEIGHT OF LOAD IN MINING VEHICLE

[0001] The invention relates to a method of determining the weight of a load in a mining vehicle, in which method the load weight is determined on 5 the basis of measuring signals obtained from separate measuring means.

[0002] The invention further relates to an arrangement for determining the weight of a load in a mining vehicle, which arrangement comprises means for determining the weight of the load.

[0003] Mining vehicles, such as dumpers and wheel loaders, transport blasted rock from a blasting location to a dump location. Because this is a fairly high-speed operation and the transportation distances are relatively short, weighing must be done while the vehicle is moving so as not to disturb production. For the following process, it is, however, necessary to know how much blasted rock has been transported for further processing. Real-time 10 weighing information makes it possible to already monitor material flows inside the mine, thus facilitating production control and planning. Planning for preventive maintenance of machines is also made possible by utilising real-time 15 weighing information.

[0004] A known solution weighs a load by measuring the cylinder 20 pressure caused by the load in the lifting cylinder that moves the system made up of lifting arms and a bucket or dump box. The pressure is measured on both sides of the lifting cylinder several times during a certain measuring period, and the load in the bucket is calculated on the basis of the average of the obtained pressure differences. The effect of the tilting of the machine and the 25 position of the lifting arms or dump box on the pressure difference measured in the lifting cylinder is compensated by means of compensation coefficients. The calculation method is linear and load determination is done while the machine is moving. When calibrating the measuring system, pressure is first measured with an empty bucket or dump box and then by using a load having a known 30 weight in the bucket or dump box.

[0005] In a stable state, the obtained measuring values are relatively correct and the load in the vehicle can be determined at an adequate accuracy. The problem is, however, that due to the quickly driven and short distances, weighing must be done during the drive, in which case the tilting of 35 the vehicle, bumps on the road and several other factors affect the final result of the weighing, and in certain situations, a systematic error towards one direc-

tion may easily occur. In addition, a problem with the solution is applying a linear method to a non-linear system and that even additional measurings used are not enough to compensate for all errors caused by drive-time measuring in the level of the pressure signal. One drawback is using a fixed measuring time

5 when calculating the average of the pressure differences from measuring signals oscillating at varying period lengths.

[0006] WO publication WO99/09379 discloses a method that utilises a neural network and fuzzy logic to determine the weight of a mining vehicle load on the basis of measuring signals measured by sensors. Variables to be

10 measured can be for instance the cylinder pressure of the lifting cylinders of a bucket or dump box, the tilting of the vehicle in both longitudinal and lateral direction and the position of the lifting arms of the bucket or the position of the dump box. The weight of the payload in the vehicle can be determined on the basis of the measured variables and the dimensions and geometry of the

15 bucket or dump box mechanics. A non-linear model based on a neural network and fuzzy logic leads to better weighing results than the linear method described above, but the drawbacks of this method are the calibration of the machine, the large amount of training data required to define a calculation algorithm, and the fact that the calculation algorithm is machine-specific.

[0007] US publication 4,919,222 discloses a method and apparatus for determining the weight of a load in a loading vehicle. Determining the load weight is based on measuring the cylinder pressure of the lifting cylinders of the bucket and the position of the lifting arms of the bucket when the bucket is lifted. A signal representing the load weight is defined on the basis of the cylinder pressure of the lifting cylinders and the position of the lifting arms of the bucket and any random pressure variations in the measurements are removed using curve fitting and averaging. The resulting curve representing the load weight is interpolated or extrapolated in relation to curves defined during the calibration of the apparatus for the purpose of determining the weight of the

25 load in the bucket. A drawback in the method described in the publication is, however, that the method is dependent on the lifting rate of the bucket that needs to be taken into consideration in the method. In addition, when the track of the loading vehicle is very bumpy, thus causing the vehicle to tilt quite a lot, it is not possible to obtain a sufficiently accurate weighing result.

[0008] FI patent 94,677 discloses a method based on measuring the deformation of structures for measuring loads directed to structures, espe-

cially the weight of a load in a vehicle. The method is suitable for calculating the load caused by static loads that are practically stationary in relation to the structures, but it cannot be used to calculate the load in a moving vehicle.

[0009] It is an object of the present invention to provide a new 5 method and arrangement for weighing the load of a mining vehicle, with which method and arrangement weighing can be done at a sufficient accuracy even when the vehicle is moving.

[0010] The method of the invention is characterized in that a non-linear Kalman filter is used to determine the weight of the load.

10 [0011] Further, the arrangement of the invention is characterized in that the arrangement comprises a calculation unit that is arranged to utilise a non-linear Kalman filter.

[0012] The essential idea of the invention is that the weight of a 15 load in a mining vehicle is determined by a non-linear Kalman filter that estimates the weight of the load in the vehicle, which load weight cannot be directly measured, by means of measuring signals obtained from measuring means located in the vehicle.

20 [0013] The invention provides the advantage that by using a non-linear Kalman filter, a better estimate can be made on the weight of the vehicle load, because to solve a non-linear problem, a non-linear method is used, by means of which it is also possible to minimise the impact of the noise included in the measurements on the estimated load weight. Another advantage is that the calibration of the method is simple and that the method need not be specifically trained to identify different masses. Further, the determination of the 25 load weight is done faster and more accurately than in the prior art methods.

[0014] The invention is described in more detail in the attached drawings, in which

Figure 1 is a schematic representation of a dumper used in mines, to which the method of the invention is applied,

30 Figure 2 is a schematic representation of a wheel loader used in mines, to which the method of the invention is applied,

Figure 3 is by way of example a schematic representation of an application of a non-linear Kalman filter and an apparatus that can be used to determine the weight of the load for instance in the dumper of Figure 1, and

35 Figure 4 is a schematic representation of the operating principle of the non-linear Kalman filter.

[0015] Figure 1 is a schematic representation of a dumper having a body 1 on wheels and a dump box 3 fastened at its rear end by joints 2 to the body 1. To empty the dump box 3, lifting cylinders 4 are connected between it and the body 1, and when the dump box 3 is lowered to its down position, its 5 front end rests on top of supports 5. Further, the dumper has sensors 6 based on gravitational force to measure the inclination of the body 1 in relation to the horizontal both in the longitudinal and lateral direction of the dumper. The inclination of the dump box 3 in relation to the body 1 can be measured for instance by using angular sensors in the joints 2 or by measuring the volume of 10 pressure fluid fed into the lifting cylinders 4 and calculating the inclination of the dump box 3 on the basis of it and by means of the geometry between the cylinder 4 fastening points and the joints 2.

[0016] Figure 2 is a schematic representation of a wheel loader having a body 1 on wheels and a bucket 9 fastened to it on lifting arms 7 through 15 joints 8, and the bucket turns around joints 10 in relation to the lifting arms 7. A separate tilting cylinder 11 tilts the bucket 9 in relation to the lifting arms 7, and a lifting cylinder 4 between the lifting arms 7 and the body 1 lifts the bucket 9. Further, the wheel loader has in the manner shown in Figure 1 inclination sensors 6 based on gravitational force for measuring the inclination of the wheel 20 loader in relation to the horizontal on the basis of earth's gravity in both longitudinal and lateral direction of the wheel loader. The position of the bucket 9 in the elevation of the body 1 can be defined by using angular sensors in the joints 8, for instance, and calculating on the basis of the measuring information provided by them and using the geometry of the lifting arms 7 the lifting height 25 of the bucket 9 when it is turned in the most upright position by means of its turning cylinder 11. Alternatively, the lifting height can also be defined by measuring the volume of pressure fluid fed into the cylinder 4, whereby it is possible to calculate the lifting height on the basis of said volume and the length of the joints and the cylinder 4.

[0017] Figure 3 is a schematic representation of an apparatus utilising a non-linear Kalman filter and suitable for determining for instance the weight of a load transported by a dumper according to Figure 1, with which apparatus it is possible to measure the load in the dumper when the vehicle is either moving or stationary, in which case the method and apparatus of the 35 invention can also be utilised in connection with an automatic filling of the bucket of a wheel loader to make sure that the bucket is full. For the actual

measuring, measuring sensors or measuring means are used, of which two measuring sensors 2a and 2b are strain gauges, for instance, that are mounted in a suitable place with respect to the joints 2 of the dump box 3 on both sides of the dumper body 1. Further, the apparatus comprises sensors 4a

5 and 4b for measuring the pressures of the pressure fluid of the lifting cylinders 4 on both the side of the lifting cylinders 4 where the pressure fluid is fed and the side from which the pressure fluid flows out. By means of these sensors, the weight of a load can be defined at a sufficient accuracy in a basically static situation on a horizontal base.

10 [0018] Measuring signals from the strain gauges 2a and 2b are forwarded through amplifiers 12 to a calculation unit 13 that calculates the position of the dump box 3 that has been defined as described earlier, and from the calculation unit 13, the parameter describing the position of the dump box 3 is forwarded to the input of a block 14 implementing the non-linear Kalman filter. The calculation of the position of the dump box 3 can also be included as part of the actual Kalman algorithm. The block 14 implementing the non-linear Kalman filter also receives measuring signals from the pressure sensors 4a and 4b, the temperature of the pressure fluid from a temperature sensor 4c of the cylinder 4 and the inclination of the vehicle measured by the inclination sensors 6. The block 14 can be a microprocessor, signal processor or another corresponding calculation unit capable of performing pre-programmed functions.

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[0019] When weighing the load while the dumper is either stationary or moving, the operator lifts the dump box 3 in such a manner that it detaches from the supports 5 shown in Figure 1. An indicator light then lights in front of the operator as a sign that only the cylinders 4 and joints 2 support the dump box 3. After this, the operator presses the button for weighing the load. The weighing can also start automatically after a certain period of time has elapsed since the dump box was lifted. The block 14 implementing the non-linear Kalman filter estimates the weight of the load in the vehicle on the basis of the inclination of the dump box 3 calculated in the calculation unit 13, the measured cylinder pressures, the temperature of the pressure fluid and the tilting of the vehicle. Figure 3 also shows a memory unit 15 for storing for instance the estimated weight of the load and other values measured, calculated or estimated during the estimation of the load weight. The memory unit 15 also stores the initial values required by the non-linear Kalman filter for beginning

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the estimation process and described in the description of the operation of the non-linear Kalman filter of Figure 4. When beginning the estimation process, the initial values are read from the memory unit 15 to the block 14 implementing the non-linear Kalman filter. The memory unit 15 can also be arranged as 5 part of the calculation unit 14, but for clarity's sake, the memory unit 15 is shown as a separate component in Figure 3.

[0020] Figure 4 shows on a general level the operation of the non-linear Kalman filter used in estimating the weight of a load to be weighed. The model of the weighing system, which comprises the dump box 3 or bucket 9 of 10 the mining vehicle, the lifting arms 7 and the lifting cylinders 4 and/or tilting cylinder 11 to move them, and the measuring means described above, is dynamic, non-linear and discretely-timed. The dynamics of the system can be described by the equation

$$15 \quad \mathbf{x}(k+1) = \mathbf{f}[k, \mathbf{x}(k)] + \mathbf{v}(k), \quad (1)$$

wherein $\mathbf{x}(k+1)$ is the actual state of the system at the time instant $k+1$, $\mathbf{f}()$ is a non-linear function corresponding to the state transition matrix of the system, $\mathbf{x}(k)$ is the actual state of the system at an earlier time instant k and vector $\mathbf{v}(k)$ 20 is white process noise with a zero mean value that describes a modelling error between the actual system and the model made of the system, the modelling error having the expected value of

$$E[\mathbf{v}(k)] = 0$$

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and the variance of

$$E[\mathbf{v}(k)\mathbf{v}(j)^T] = \mathbf{Q}(k)\delta_{kj},$$

30 wherein $\mathbf{Q}(k)$ is a covariance matrix of the process noise, i.e. model noise, δ_{kj} is Kronecker's delta, wherein $\delta_{kj} = 1$ when $k = j$ and otherwise 0, and T describes the transposition operation of the matrix. For instance, when defining the weight m of the dumper load, the system model can take into consideration 35 the high and low pressures P_y and P_a of the lifting cylinder of the dump box, the tilting γ of the machine, the position s of the dump box, and the temperature L of the pressure fluid, e.g. hydraulic oil. A state vector \mathbf{x} of the non-linear

state model of the weighing system of the vehicle would then comprise six elements

$$\mathbf{x} = [m, p_y, p_a, \gamma, s, L]^T.$$

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Of these, all others but the actual weight m of the load are measurable variables. The measurement of the temperature L of the pressure fluid can also be left out of the above-mentioned measurements without any essential change in the accuracy of the estimate of the load weight m . The dependency of the load 10 weight m on said measurements is non-linear, i.e. the function $f()$ describing the dynamics of the weighing system shown in formula (1) is non-linear. In addition, other factors that are not directly measurable can also be taken into consideration in the function $f()$ describing the model of the load weight m .

15 [0021] The estimation of the state of the system and thus also the weight m of the load using a non-linear Kalman filter is done as follows.

[0022] At the time instant k , the actual state of the system is $\mathbf{x}(k)$. 20 The actual state 21 at the next time instant $k + 1$ is according to formula (1)

$$\mathbf{x}(k+1) = f[k, \mathbf{x}(k)] + \mathbf{v}(k),$$

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and the corresponding measurement 22 at the time instant $k + 1$ is

$$\mathbf{z}(k+1) = h[k+1, \mathbf{x}(k+1)] + \mathbf{w}(k+1), \quad (2)$$

25 wherein the measurement function $h()$ is generally a non-linear function, but within the scope of this invention, the measurement function $h()$ can also be linear, and $\mathbf{w}(k)$ is white measuring noise with a zero mean value that describes the error summed to the measurements from the measuring devices and measuring environment. The expected value of the measuring noise $\mathbf{w}(k)$ 30 is

$$E[\mathbf{w}(k)] = 0$$

and its variance is

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$$E[\mathbf{w}(k)\mathbf{w}(j)^T] = \mathbf{R}(k)\delta_{kj},$$

wherein $\mathbf{R}(k)$ is the covariance matrix of the measuring noise.

[0023] The estimate $\hat{\mathbf{x}}(k|k)$ 23 of the actual state $\mathbf{x}(k)$ at the time instant k is an approximation of the conditional expected value of the actual state,

$$\hat{\mathbf{x}}(k|k) \approx E[\mathbf{x}(k)|\mathbf{Z}^k]$$

10 formed on the basis of measurements $\mathbf{Z}^k = \{\mathbf{z}(1), \mathbf{z}(2), \dots, \mathbf{z}(k)\}$ accumulated by the time instant k . So as to be able to estimate the state of the system at the time instant $k+1$, the non-linearities of the system must be linearized from the function $\mathbf{f}(\cdot)$ describing the dynamics of the model close to the state estimate $\hat{\mathbf{x}}(k|k)$ 23 of the time instant k . The Taylor series development is used in the 15 linearization, and depending on whether only first-order terms are used or whether second-order terms are also included, either a first or second-order filter is obtained. Linearization of a non-linear function is also used when calculating a measurement prediction $\hat{\mathbf{z}}(k+1|k)$ 25. By means of the Taylor series development, the following representation is obtained for a second-order filter

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$$\begin{aligned} \mathbf{x}(k+1) = & \mathbf{f}\left[k, \hat{\mathbf{x}}(k|k)\right] + \mathbf{f}_x(k)\left[\mathbf{x}(k) - \hat{\mathbf{x}}(k|k)\right] \\ & + \frac{1}{2} \sum_{i=1}^{n_x} e_i \left[\mathbf{x}(k) - \hat{\mathbf{x}}(k|k) \right]^T f_{xx}^i(k) \left[\mathbf{x}(k) - \hat{\mathbf{x}}(k|k) \right] + \mathbf{KAT} + \mathbf{v}(k) \end{aligned} \quad (3)$$

25 wherein n_x is the number of states that in this case is six, e_i is an i^{th} n_x -dimensional basis vector whose i^{th} component is one and other components are zero, KAT describes higher-order terms that in this case can be excluded and

$$\mathbf{f}_x(k) = \left[\nabla_x \mathbf{f}(k, \mathbf{x})^T \right]^T \Big|_{\mathbf{x} = \hat{\mathbf{x}}(k|k)} \quad (4)$$

30 is the Jacobian 29 of the vector \mathbf{f} calculated at $\hat{\mathbf{x}}(k|k)$ 23, and

$$f_{xx}^i(k) = \nabla_x^T f^i(k, x) \Big|_{x=\hat{x}(k|k)} \quad (5)$$

is a part 29 of the Hesse matrix calculated on the basis of the i^{th} component of the vector \mathbf{f} .

5 [0024] After the linearization, the prediction $\hat{x}(k+1|k)$ 24 of the state

$$\begin{aligned} \hat{x}(k+1|k) &= E\left\{ \mathbf{f}\left[k, \hat{x}(k|k) \right] \right\} + E\left\{ \mathbf{f}_x(k) \left[x(k) - \hat{x}(k|k) \right] \right\} \\ &+ E\left\{ \frac{1}{2} \sum_{i=1}^{n_x} e_i \left[x(k) - \hat{x}(k|k) \right]^T f_{xx}^i \left[x(k) - \hat{x}(k|k) \right] \right\} \end{aligned} \quad (6)$$

10 at the time instant k for the time instant $k+1$ is obtained as a conditional expected value of equation (3) formed on the basis of the measurements Z^k accumulated by the time instant k when the terms of a higher than second order are excluded due to their minor effect. The accuracy of the calculation can, however, be increased by taking the terms of a higher than second order into consideration. Because on average, a first-order term has a zero mean value
15 on the basis of

$$\hat{x}(k|k) \approx E[x(k)|Z^k],$$

20 the following is obtained as the state prediction $\hat{x}(k+1|k)$ 24 for the time instant $k+1$

$$\hat{x}(k+1|k) = \mathbf{f}\left[k, \hat{x}(k|k) \right] + \frac{1}{2} \sum_{i=1}^{n_x} e_i \text{tr}[f_{xx}^i(k) P(k|k)] \quad (7)$$

25 wherein the **tr** operation is the sum of the diagonal elements of the square matrix and $P(k|k)$ 28 is the covariance of the state at the time instant k . The prediction error of the state is obtained by subtracting equation (7) from equation (3). By multiplying the thus obtained prediction error by its own transposition and by producing a conditional expected value from it in relation to the measurements Z^k , the predicted covariance $P(k+1|k)$ 30 of the state is obtained
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$$\begin{aligned} P(k+1|k) &= f_x(k)P(k|k)f_x(k)^T \\ &+ \frac{1}{2} \sum_{i=1}^{n_x} \sum_{j=1}^{n_x} e_i e_j^T \text{tr}[f_{xx}^i(k)P(k|k)f_{xx}^j(k)P(k|k)] + Q(k). \end{aligned} \quad (8)$$

[0025] On the basis of the state prediction calculated in formula (7), it is possible to calculate at the time instant k a prediction $\hat{z}(k+1|k)$ 25 for the 5 measurement for the time instant $k+1$

$$\hat{z}(k+1|k) = h \left[k+1, \hat{x}(k+1|k) \right] + \frac{1}{2} \sum_{i=1}^{n_z} e_i \text{tr}[h_{xx}^i(k) + P(k+1|k)], \quad (9)$$

10 wherein e_i is i^{th} n_z -dimensional basis vector, and in the case of this example, n_z is five, i.e. the number of measurements. On the basis of the actual measurement $z(k+1)$ 22 and the measurement prediction $\hat{z}(k+1|k)$ 25, it is possible to calculate the residual, i.e. innovation, $v(k+1)$ 26 of the measurement at the time instant $k+1$

$$15 \quad v(k+1) = z(k+1) - \hat{z}(k+1|k), \quad (10)$$

and the related covariance $S(k+1)$ 31 of the innovation is

$$\begin{aligned} S(k+1|k) &= h_x(k+1)P(k+1|k)h_x(k+1)^T \\ &+ \frac{1}{2} \sum_{i=1}^{n_x} \sum_{j=1}^{n_x} e_i e_j^T \text{tr}[h_{xx}^i(k+1)P(k+1|k)h_{xx}^j(k+1)P(k+1|k)] + R(k), \end{aligned} \quad (11)$$

20 wherein corresponding to formulas (3) to (5)

$$h_x(k+1) = \left[\nabla_x h(k+1, x)^T \right]^T \Big|_{x=\hat{x}(k+1|k)} \quad (12)$$

and

$$25 \quad h'_{xx}(k+1) = \left[\nabla_x^T h'(k+1, x) \right] \Big|_{x=\hat{x}(k+1|k)}. \quad (13)$$

[0026] The amplification $W(k+1)$ 32 of the filter can be calculated from the formula

$$\mathbf{W}(k+1) = E[\tilde{\mathbf{x}}(k+1)\mathbf{v}(k+1)^T | \mathbf{Z}^k], \quad (14)$$

wherein $\tilde{\mathbf{x}}(k+1)$ is the prediction error of the state $\mathbf{x}(k+1)$ 21 based on the information available at the time instant k . The updated estimate of the state, i.e. the filtered value $\hat{\mathbf{x}}(k+1|k+1)$ 27 of the state at the time instant $k+1$ based on the information available at the time instant $k+1$ is

$$\hat{\mathbf{x}}(k+1|k+1) = \hat{\mathbf{x}}(k+1|k) + \mathbf{W}(k+1)\mathbf{v}(k+1) \quad (15)$$

10 and the updated covariance $\mathbf{P}(k+1|k+1)$ 33 of the state at the time instant $k+1$ based on the information available at the time instant $k+1$ is

$$\mathbf{P}(k+1|k+1) = \mathbf{P}(k+1|k) - \mathbf{W}(k+1)\mathbf{S}(k+1)\mathbf{W}(k+1)^T. \quad (16)$$

15 [0027] The estimation of the system state, i.e. according to this invention, also the estimation of the load weight m , by means of a Kalman filter can, in principle, be divided into three parts: predicting the state, calculating the amplification of the filter, and calculating the residual of the measurement, and 20 on the basis of these, it is possible to calculate an estimate for the system state, and in this case, especially for the load weight m . The uncertainties in the weighing system model and the measuring devices affect through the state covariance the amplification of the filter, with which the residual of the measurement is weighted in such a manner that in updating the state estimate, the 25 information provided by the measurements on the state of the system and the state calculated on the basis of the system model are taken into account to a suitable extent, since neither of them alone is completely reliable, i.e. corresponds to the actual system. The obtained updated values are further used in forming the estimate of the next time instant. These calculation cycles are 30 repeated until the state provided by the filter as its output, i.e. in this case especially the weight m of the vehicle load, has settled to a certain level that thus corresponds to the estimate of the weight m of the load in the vehicle. The estimation can be ended for instance when the variance of the load weight estimate is below a predefined limit value that can be changed, i.e. it is a parameter of the algorithm. To begin calculation the initial value $\hat{\mathbf{x}}(0|0)$ of the state es- 35

timate, the state covariance $P(0|0)$ corresponding to the initial state, and the uncertainties of the weighing system model and the measuring devices are required, all of these being stored in the memory unit 15, from which they are read to the block 14 implementing the non-linear Kalman filter when weighing 5 is started. Values set at the factory to the vehicle in question can be used as the initial values. The first measurement can also be used as the initial value for the states to be measured, in which case the actual estimate calculation is started from the second measurement. The reason why the estimated value of 10 the load weight m does not immediately at the first Kalman filter calculation cycle give the correct result is due to the fact that the calculation is started from the initial value of the state that is not necessarily correct. In addition, there is interference in the measuring signals especially at the beginning of the measurement that first must be filtered by the Kalman filter.

[0028] To calibrate the weighing system, the vehicle is loaded with a 15 test load of known weight. To perform calibration for an empty dump box or loading vehicle, it is enough to weigh the empty bucket and one known test load, but it is also possible to use several test loads of different weights. The calibration is performed specifically for each machine. Further, the calibration can be performed again during the use of the machine to compensate for the 20 impact of changes caused by aging of the machine or change of components. In connection with the calibration, the non-linear Kalman filter can also be used to estimate the parameters of the non-linear model of the weighing system.

[0029] Correspondingly, in the manner described above, the weighing can be done by means of a wheel loader, in which case the position of the 25 bucket and other factors can easily be taken into account. In the case of a wheel loader, it is in principle possible to use the measuring diagram of Figure 3, in which case the position of the bucket 9 in the elevation of the body 1 and/or the inclination of the lifting arms 7 are taken into account in the weighing system model. Thus, the state vector x of the model and the functions representing the system dynamics change from what is stated above while the 30 principle of load weight m estimation remains the same.

[0030] The drawings and the related description are only intended 35 to illustrate the idea of the invention. The invention may vary in detail within the scope of the claims. Thus, the structure of the mining vehicle need not be exactly as described in Figures 1 and 2, but the essential thing is that the estimation of the load weight is based on estimating by means of a non-linear Kalman

filter the states of a non-linear model formed of the weighing system. Special applications of the Kalman filter, such as a Wiener filter or the like, can be used in a corresponding manner to determine the weight of the load in the mining vehicle.

CLAIMS

1. A method of determining the weight of a load in a mining vehicle, in which method the load weight (m) is determined on the basis of measuring signals obtained from separate measuring means, **characterized** in that a non-linear Kalman filter is used to determine the weight (m) of the load.
- 5 2. A method as claimed in claim 1, **characterized** in that a non-linear state model is formed of a weighing system comprising a dump box (3) or bucket (9) of a mining vehicle, lifting arms (7) and lifting cylinders (4) and/or tilting cylinder (11) used to move them, and measuring means, and the states of the non-linear state model are estimated by means of the non-linear Kalman filter.
- 10 3. A method as claimed in claim 2, **characterized** in that at least one state of the non-linear model of the weighing system comprises the load weight (m) of the mining vehicle.
- 15 4. A method as claimed in claim 2 or 3, **characterized** in that at least one state of the non-linear model of the weighing system comprises the pressure (p_y , p_a) of the pressure fluid of the lifting cylinder (4).
- 20 5. A method as claimed in claim 4, **characterized** in that at least one state of the non-linear model of the weighing system comprises the temperature (L) of the pressure fluid of the lifting cylinder (4).
6. A method as claimed in claim 5, **characterized** in that at least one state of the non-linear model of the weighing system comprises the inclination (γ) of the mining vehicle in relation to the horizontal.
- 25 7. A method as claimed in claim 6, **characterized** in that at least one state of the non-linear model of the weighing system comprises the inclination of the dump box (3) in relation to the mining vehicle or the position of the mining vehicle bucket (9) and/or the inclination of the lifting arms (7) in the elevation of the mining vehicle body (1).
- 30 8. A method as claimed in any one of the preceding claims, **characterized** in that pre-set values are used as the values of the initial state of the non-linear Kalman filter.
9. A method as claimed in claim 8, **characterized** in that values set at the factory are used as the values of the initial state of the non-linear Kalman filter.

10. A method as claimed in any one of the preceding claims, **characterized** in that the estimation of the load weight is ended after the load weight estimate settles at a certain level.

11. A method as claimed in claim 10, **characterized** in that 5 the estimation of the load weight is ended after the value of the variance of the load weight estimate is below a preset limit value.

12. A method as claimed in any one of the preceding claims, **characterized** in that the non-linear model of the weighing system is calibrated using one or more test loads of known weight.

10 13. An arrangement for determining the weight of a load transported by a mining vehicle, which arrangement comprises means for determining the weight (m) of the load, **characterized** in that the arrangement comprises a calculation unit (14) arranged to utilise a non-linear Kalman filter.

14. An arrangement as claimed in claim 13, 15 **characterized** in that the arrangement comprises measuring means for forming measuring signals to be utilised in determining the weight (m) of the load.

15. An arrangement as claimed in claim 14, **characterized** in that the arrangement comprises measuring means 20 (4a, 4b) for measuring the pressure (p_y , p_a) of the pressure fluid of the lifting cylinder (4).

16. An arrangement as claimed in claim 15, **characterized** in that the arrangement comprises measuring means 25 (4c) for measuring the temperature (L) of the pressure fluid of the lifting cylinder (4).

17. An arrangement as claimed in claim 16, **characterized** in that the arrangement comprises measuring means (6) for measuring the inclination (γ) of the mining vehicle in relation to the horizontal.

30 18. An arrangement as claimed in claim 17, **characterized** in that the arrangement comprises measuring means for measuring the inclination of the dump box (3) in relation to the mining vehicle or for measuring the position of the bucket (9) of the mining vehicle and/or the inclination of the lifting arms (7) in the elevation of the body (1) of the mining 35 vehicle.

19. An arrangement as claimed in any one of claims 14 to 18, characterized in that the arrangement comprises a calculation unit (14) for estimating with a non-linear Kalman filter the states of the non-linear state model of the weighing system formed of the dump box (3) or bucket (9) of the mining vehicle, the lifting arms (7) and lifting cylinders (4) and/or tilting cylinder (11) used to move them, and measuring means.

5 20. An arrangement as claimed in claim 19, characterized in that the arrangement comprises a memory unit (15) for storing the estimated states of the state model and/or the initial values required in the estimation.

10 21. An arrangement as claimed in claim 20, characterized in that the calculation unit (14) for estimating the states of the non-linear state model with a non-linear Kalman filter comprises the memory unit (15).

15 22. An arrangement as claimed in any one of claims 18 to 21, characterized in that the arrangement comprises a calculation unit (13) for determining the position of the dump box (3) of the mining vehicle or the position of the bucket (9) and/or the inclination of the lifting arms (7).

20 23. An arrangement as claimed in claim 22, characterized in that the calculation unit (14) that estimates with the non-linear Kalman filter the states of the non-linear state model of the mining vehicle weighing system comprises the calculation unit (13) calculating the position of the dump box (3) or bucket (9) of the mining vehicle and/or the inclination of the lifting arms (7).

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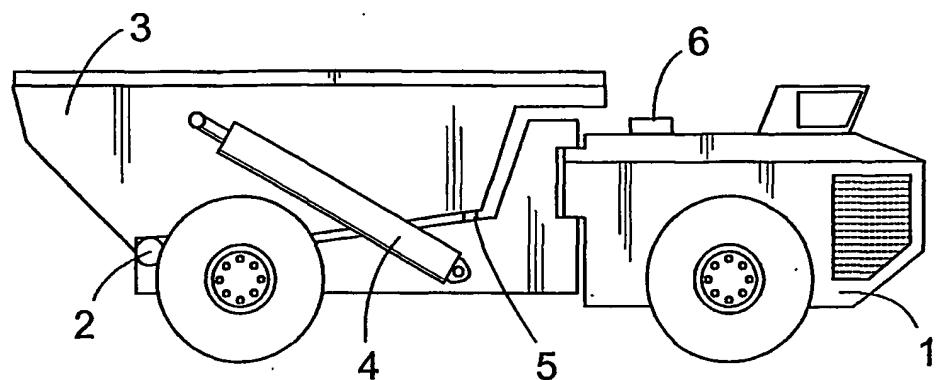


FIG. 1

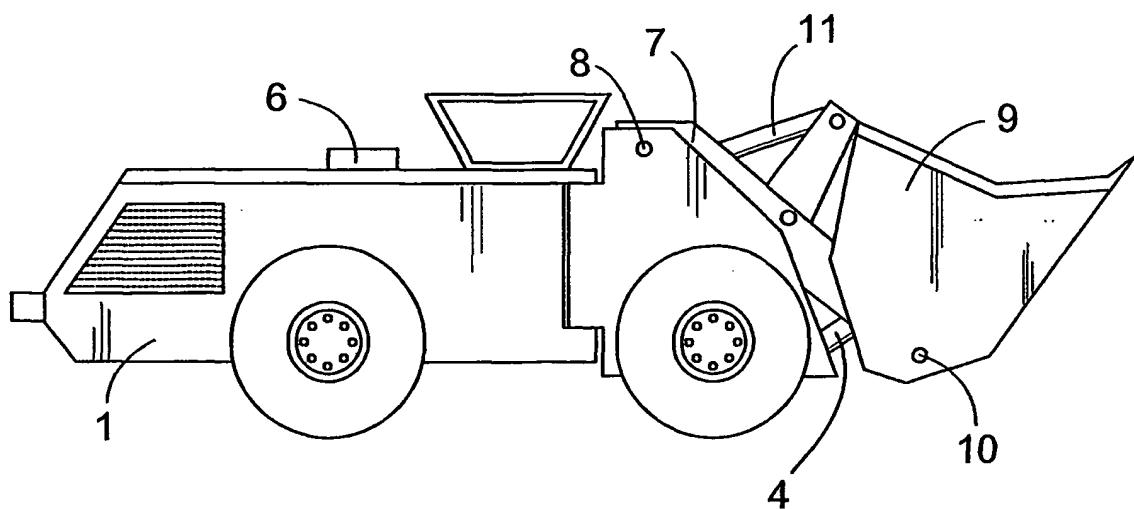


FIG. 2

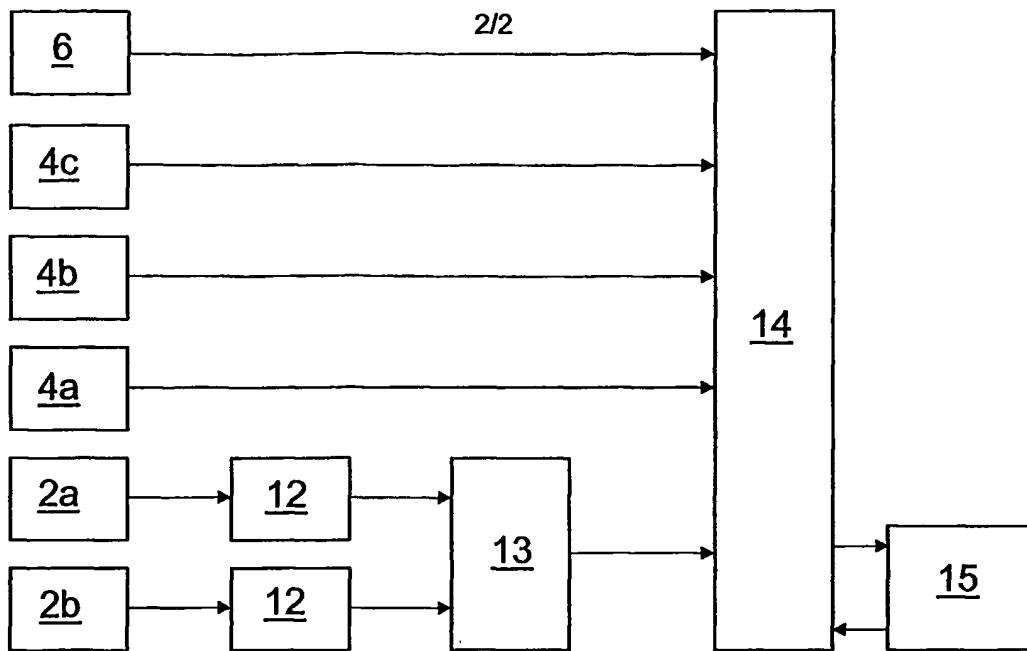


FIG. 3

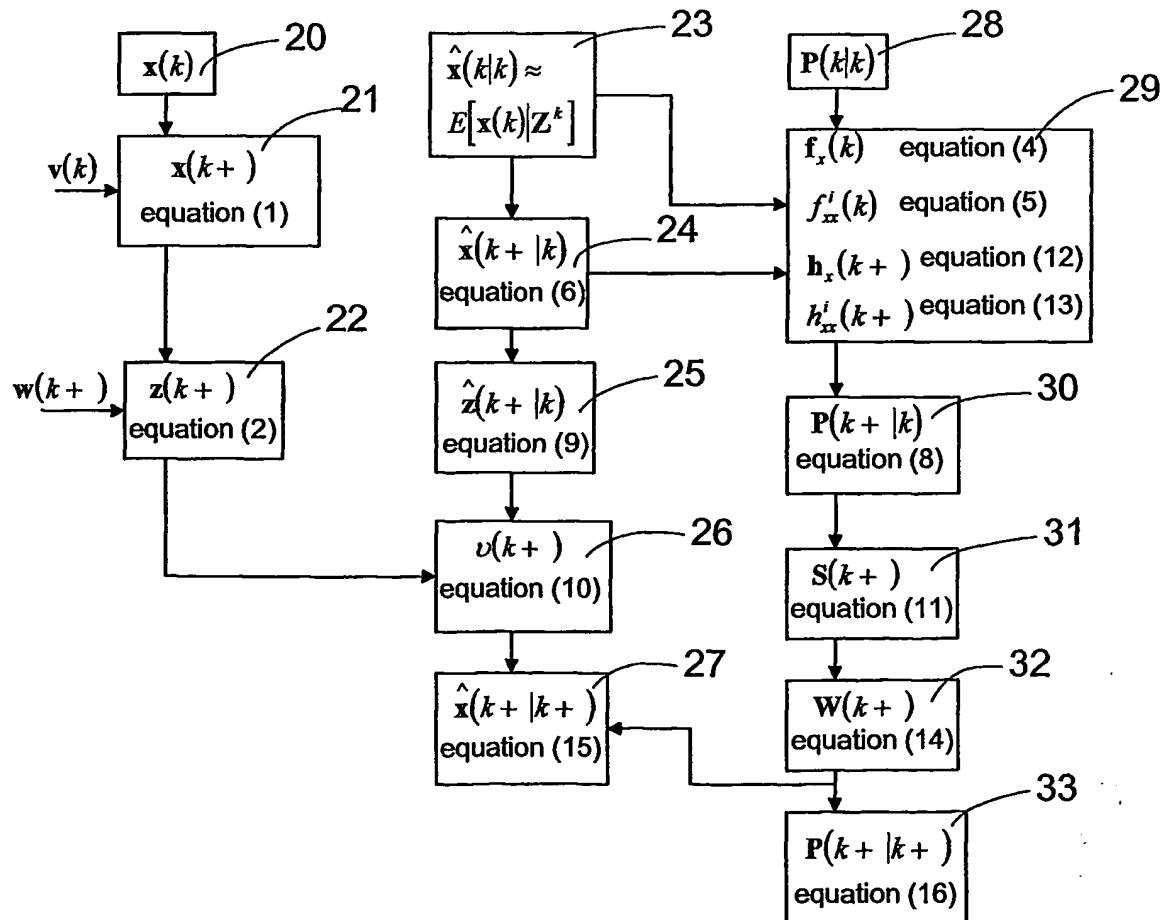


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 01/00973

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01G 19/12, B60P 5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01G, B60P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	M.NIEDZWIECKI et al "Application of adaptive filtering to dynamic weighing of vehicles." Control Eng.practice, Vol.4.No.5,pp 635-644,1996. See the whole document. --	1,13,14
A	US 4954975 A (PAUL R.KALATA), 4 Sept 1990 (04.09.90), see the whole document --	1-23
A	US 4893262 A (PAUL R. KALATA), 9 January 1990 (09.01.90), see the whole document -----	1-23

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2002	18 -02- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson /itw Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 01/00973

06/11/01

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US 4893262 A	09/01/90	DE	3910028 A	19/10/89
		JP	2022703 A	25/01/90
		JP	2726089 B	11/03/98
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		JP	1815806 C	18/01/94
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